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BEHAVIOR OF CONVERGENT LADY BEETLES IN RELATION TO GREENBUG CONTROL IN SORGHUM

Observations and Preliminary Tests

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ABSTRACT

Convergent lady beetles, *Hippodamia convergens* Guérin-Méneville, were imported from California and released in Kansas to study handling procedures and their behavior as biological agents against the greenbug, *Schizaphis graminum* (Rodani), in sorghum. Marking with a flourescent dye and counting at night with a black-light lamp was the best of several marking techniques tried, but this technique still was not ideal. Even and rapid distribution of imported beetles in a sorghum field was not attained, although hand distribution was expedited by using a modified grass seeder. Attempts at keeping beetles in the field where they were released by providing shelter, offering water, and releasing at night were generally unsuccessful. California beetles were not as effective as natives in keeping greenbugs under control on plants in the greenhouse. In laboratory tests the California beetles' effectiveness improved at high temperatures, but longevity was reduced. Native beetle populations appeared to be highly mobile because there was little reproduction in sorghum fields; the adults may have migrated to overwintering areas while food was still available. Summer-fall aggregations of estivohibernating beetles were found at the highest elevation in several areas, although these locations were not near sorghum fields.

INTRODUCTION

The greenbug, *Schizaphis graminum* (Rondani), is a major pest of small grains. In 1968 a new biotype of the greenbug caused extensive damage to sorghum in the Great Plains. Populations of greenbugs were as high as 40,000 per plant before parasites and predators finally reduced the infestation, but only after extensive damage had been done. This lag between the buildup of greenbugs and that of their insect enemies has often been evident, not only to entomologists, but also to farmers. The introduction of beneficial insects during this lag period might slow or prevent such a buildup of greenbugs.

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The convergent lady beetle, *Hippodamia convergens* Guérin-Méneville, is the most common predacious insect species present in sorghum fields in the Midwest. Farmers attempted to increase beetle numbers in 1969 and 1970 by obtaining hibernating beetles from commercial companies in California and releasing them in fields at about 1 gallon (roughly 75,000 beetles) per 10 acres.

Excellent behavorial studies of lady beetles were done by Hagen (*4*)[3] and Stewart et al. (*10*), among others. Fenton and Dahms (*3*), in a study closely related to ours, concluded that *H. convergens* was not effective when released for the control of greenbugs in wheat, but their test area was only 40 acres. We believed that such releases would have a better chance of success if (1) beetles were released early when greenbug populations were low and (2) releases were made in an area larger than individual fields.

Our study was undertaken in the spring of 1970, when beetles were to be released on 10,000 acres of sorghum and an additional 10,000 acres was to be used as a control. Problems with obtaining beetles and getting an early, uniform infestation of greenbugs (a heavy, late infestation did occur) prevented the study from being done in its entirety. However, all participants agreed that the few gallons of beetles that were received offered an opportunity to obtain needed preliminary information on the behavior of "imported" beetles. In this report we describe our experience in handling the beetles and the results of several behavioral tests.

[3] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

LADY BEETLE HANDLING

The beetles were obtained from the Bio-Control Co., Auburn, Calif. They were captured while in estivohibernation in crevices of the Sierra Nevada, packed in wood shavings, and shipped by air to Manhattan, Kans.

Two types of beetles were obtained: 1 gallon of "old beetles," beetles that had overwintered in the mountains, and 12 gallons of "new beetles," beetles that shortly before capture had returned from feeding areas in the Imperial Valley. Both groups were almost entirely the one species, *H. convergens*. There were about 75,000 beetles in a gallon. The sexes were nearly equal (111 males to 89 females in a sample of 200). Sexing of beetles was fairly rapid, but exposing the internal genitalia injured the individuals.

We stored the beetles in the shipping containers at about 45° F for as long as 3 months with little mortality. The containers were frequently sprayed with water.

Native beetles were collected from fields as needed. Handling procedures were similar to those for California beetles.

Marking

To account for released beetles, they have to be marked.

Thirteen aerosol sprays, some

being different colors of the same brand, were tried. Two lacquer sprays were highly toxic to the beetles (and irritating to us also), and there was about 20% mortality of beetles within 10 minutes after spraying. Another paint glued beetles to the container surface. An epoxy paint would not adhere to the elytra. Some enamels gave a long-lasting paint job with little solvent toxicity, but too many beetles acted abnormally; that is, they frequently crash-landed. Magnification indicated that the antennae and eyes were paint-coated. The least toxic was a hair spray that can be obtained in silver and gold colors. A big advantage of this spray was that beetles could clean it off their antennae. Although it was fairly water repellent, it rubbed off the beetles within 3 to 6 days and was relatively expensive.

Other materials were then tested, and a fluorescent dye called Day-Glo proved to be the most effective marker and was used in a release test. This dye is comparatively inexpensive, is available in several vivid colors, and remains detectable up to 1 month after application. One ounce of the dye powder in 100 cubic centimeters of acetone was used with little apparent ill effect for marking one-half gallon of beetles. Unfortunately, the dye dislodged easily onto plants, and this frequently gave false indications of the presence of beetles. Furthermore, only a heavy coating of the dye on beetles permitted detection of marked beetles during the day. Thus, a black-light lamp had to be used, and counts of marked beetles made at night, a time when native beetles could not be detected. Orange was easier to see against sorghum leaves than green, yellow, or blue.

At first, a large paper box with the top removed was tried as a spray chamber. A chalk line on the inside near the top of the box prevented most beetles from crawling out, providing the line was at least an inch wide. Beetles seemed to lose their footing and would turn back. The most frequent means of escape, however, was by flying vertically, and the open box afforded no deterrent. Finally, a box with a sliding glass top and cloth sleeve was used.

Satisfactory separation of the beetles from the packing material before spraying was not accomplished. Too many beetles hid in the wood shavings and were not sufficiently covered with the dye. On the other hand, if the beetles were to be transported over a mile or two after marking, they had to be packed in the wood shavings, or else there would have been a risk of "balling up" and thus high mortality.

Releasing Equipment

Initially, we thought about releasing beetles by hand broadcasting. Calculations indicated that about 5,000 man-hours would be needed to get an even distribution of beetles over 10,000 acres if two applications were made, and we did not have the manpower. Release from a vehicle was not practical because irrigated fields are

too soft or have cross ditches. Aerial release was certainly an alternative, but was not tried. The beetles seem to take considerable physical abuse with little ill effect. However, a special release chute would have to be fitted to an airplane or else beetles would be blown afar.

We then obtained two types of hand seeders, and these offered promise. One of these was plastic, easy to operate, had a slick inner surface in the hopper, and gave a good distribution pattern, although the cover swath was only about 15 feet. The one we bought, however, only lasted about 15 minutes before it came apart. The other seeder was a grass seeder that had to be modified. A sheet-metal hopper with beveled sides replaced the cloth one, and a baffle was added to direct the flow of beetles forward. The width of the release pattern was about 25 to 30 feet, but the application rate of beetles was too great. Even when a 40-foot swath was covered, releasing by hand still required considerable time. A compromise would have been to release in alternate strips, leaving every other strip initially uninfested. Presumably beetles would eventually move into the uninfested strips.

Releasing

We were aware that the "old beetles" would likely not stay in a field after they were released (*4*). Indeed they didn't. Upon release, about 72% took to the wing and were soon lost from sight. Another 12% crawled under clods of soil and remained at least 2 days. The remaining 16% climbed upon plants and would actively seek and destroy aphids. Native beetles caught, marked, and then released acted no better except that none was observed hiding under clods.

"New beetles" obtained from California were next released in a 10-acre field of 2- to 3-week-old sorghum at three times (table 1). At each time, one-half gallon of beetles was released near the center of the field, and counts were made at 0500, 1400, and 2100 hours for about a week. Part of the beetle counts are given in table 1.

Dislodged dye particles on plants indicated that beetle movement was almost entirely northward. This was probably related to the prevailing wind blowing from the south. There is little doubt that the beetles moved—in fact, about 99% moved out of the field without touching down, even though adequate food in the form of aphids was present. There was a slight increase in beetle population within about a 10-foot radius of the release point, but these beetles might have been injured. If all the released beetles had stayed in the field, the counts should have been between 90 and 110 beetles per 100 feet of row instead of the observed 0 to 10. Moreover, the beetle releases did not significantly affect aphid populations. On July 30, before any beetles had been released, there were about 27 corn leaf aphids, *Rhopalosiphum maidis* (Fitch), and 6 greenbugs per plant. On August 7, after 3 beetle releases, there were about 21 corn

TABLE 1.—*Representative beetle counts in sorghum after release of California lady beetles at various times*

[37,500 beetles released each time]

Time of release	Beetle count				
	Date	Time	Temp. (° F)	Light	No. beetles/ 100 ft of row
Prerelease	July 29	1400	97	Sunny	6.1
	July 30	1400	98	Cloudy	27.0
	July 31	1400	96	Sunny	9.5
July 31, 2130 h.	Aug. 1	0500	...	Dark	>.1
Aug. 1, 1330 h.	Aug. 1	1400	101	Sunny	6.7
	Aug. 1	2100	...	Dark	>.1
	Aug. 2	0500	...	Dark	>.1
Aug. 2, 0530 h.	Aug. 2	1400	102	Sunny	10.2
	Aug. 2	2100	...	Dark	>.1
	Aug. 3	0500	...	Dark	0
	Aug. 3	1400	98	Sunny	6.5
	Aug. 7	1400	98	Sunny	8.3

leaf aphids and 8 greenbugs per plant.

The comparatively high prerelease count on July 30 (table 1) is of interest since this count was made on the only cloudy day during the test. Prior observations had indicated that even native beetles move readily out of the field during the hot part of the day unless there is cloud cover.

BEHAVIORAL TESTS

Shelter Test in the Field

We thought that released beetles might be more likely to stay near the release point if shelter from the sun were provided. Also, we had noted that the beetles took water eagerly when taken from storage and allowed to warm up in the laboratory. Therefore, a three-treatment test in a pasture was undertaken. The treatments were a (1) shelter (about 2 square feet) made by placing a burlap bag on top of 12-inch high stakes, (2) a similar shelter except that the bag was sprayed with water about three times daily, and (3) no burlap bag on top of the stakes. One pint (about 9,400 individuals) of beetles was released in each treatment, and each treatment was replicated three times.

The burlap shelter significantly influenced beetles to remain within the test area (table 2). There was an indication that the water may have prevented mortality, but the test was not replicated enough to obtain proof. However, only about 4% of the released beetles stayed within the sheltered area. The dispersion from the sheltered areas may not have been as extensive as that from the unsheltered area, but this factor was not measured. Therefore, the conclusion must be that small shelters help

TABLE 2.—*Influence of shelter and water on movement and mortality of California lady beetles*

[9,400 beetles released in each shelter; treatments replicated 3 times]

Shelter	Live beetles at[1]— 24 h	48 h	Dead beetles at[1]— 24 h	48 h
Watered burlap	500b	373b	115a	70a
Dry burlap	365b	393b	315a	283a
No shelter	75a	57a	315a	297a

[1] Means not having a letter in common are significantly different at $P = 0.05$. 24-hour counts were estimates.

only slightly in preventing beetles from leaving a field. They may be of no benefit in dense vegetation such as sorghum, which provides shade itself. The need for water does not appear to be the main reason that beetles leave a field, although a source of water might retain a few if only for a day.

Cage Test in the Greenhouse

A test comparing the efficiency of California beetles with native beetles was done in the greenhouse with varying levels of greenbugs on hybrid 'RS-610' sorghum in pots. The plants were about 2 weeks old when the test was started. Plastic cages were used to confine the beetles and greenbugs on the plants. Two beetles (mainly females) were used for each of the treatments shown in table 3, and each treatment was replicated eight times.

The imported beetles lived as long as native beetles. In fact, beetles without aphids or even plants lived as long as those offered an abundance of food. Wheast, a milk product, did not seem to prolong survival, although beetles were observed feeding on it. The California beetles, however, in comparison to the native ones, did a poor job of keeping the greenbug population under control, even in the treatment where there were only 100 aphids per 2 beetles. During the 3 weeks of the test, 13 out of 24 plants (54%) died from greenbug injury in treatments with California beetles, whereas only 1 plant (4%) died in treatments with native beetles, and this plant did not die until the test had been in progress for over 2 weeks. California beetles were often observed at the top of the cages, making no attempt to feed on the aphids. Thus, the reason that imported beetles leave a field may not be a lack of food. The test indicated that each native beetle could effectively control 100 greenbugs, at least on caged plants. This level of aphid consumption is slightly higher than that reported by Hodek (7).

Temperature Test

A test was conducted in growth chambers with four daily temperature ranges (105°–80°, 90°–65°, 75°–50°, and 60°–35° F). The high temperature in each range fell within a 14-hour photoperiod. Each temperature treatment had 2

TABLE 3.—*Efficiency of California and native lady beetles in controlling greenbugs on sorghum in the greenhouse*

[2 beetles per treatment; treatments replicated 8 times]

Beetle source and treatment	Cumulative reduction (%) of aphids after[1]—					Beetle longevity[2] (days)
	2 days	5 days	7 days	14 days	21 days	
California:						
No plant	...	...	...	...	...	17
Plant + Wheast	...	...	...	...	...	16
Plant + 100 aphids	38	76	(2)	(2)	(3)	14
Plant + 200 aphids	46	69 (1)	(2)	(3)	(4)	15
Plant + 400 aphids	26	55 (1)	(1)	(3)	(6)	14
Native:						
No plant	...	...	...	...	...	14
Plant + Wheast	...	...	...	...	...	14
Plant + 100 aphids	96	99	100	...	...	17
Plant + 200 aphids	86	99	100	...	...	15
Plant + 400 aphids	65	87	89	89	98 (1)	17

[1] Figures in parentheses are cumulative number of plants killed by aphids during the 3-week test. Aphid reduction could no longer be calculated after the 5th day in treatments with California beetles because the greenbugs died when the plants died.

[2] About 32% of the beetles were alive after 21 days, when the test ended. The figures refer to the average longevity of the beetles that died during the test.

beetles and 400 aphids on sorghum leaf sections held in a plastic petri dish with ventilation holes covered with organdy, and each treatment was replicated 5 times. Fresh sorghum leaves were substituted as necessary, and a few drops of water were added daily to each petri dish.

The survival of beetles was better at lower temperatures than at higher ones (table 4). In fact, at 105°–80° and 90°–65° F about one-half of the beetles died after a week. At the lower temperatures, the beetles did not eradicate the greenbugs during the 11 days that the test was run. This test was similar to other observations in that the beetles fed readily when first taken from storage, but soon they seemed to have little interest in feeding.

OBSERVATIONS ON NATIVE BEETLES

Populations of native beetles peaked at about 12,500 per acre in the sorghum when plants were about 6 to 8 inches tall (field 1) and at about 3,000 per acre when plants were smaller and had fewer aphids (field 2). At other times the counts were as low as 2,100 per acre in field 1 and 800 per acre in field 2. This variation was not due to sampling error, judging by statistical analysis. Instead, the beetles seemed to move out of the fields during the heat of the day and move back when the temperature dropped. However, few beetles were found in weeds surrounding the field, so it is not known where the beetles stayed during their absence from the fields. The

TABLE 4.—*Effect of temperature on the feeding and longevity of California lady beetles in the laboratory*

[2 beetles and 400 aphids per temperature range; treatments replicated 5 times]

Temperature (° F)	Avg. live aphids after— 3 days	5 days	7 days	9 days	11 days	Total live beetles after— 3 days	5 days	7 days	9 days	11 days
105–80	36	0	...	...	...	9	8	4	4	2
90–65	22	3	0	...	...	10	7	5	5	3
75–50	123	94	11	3	1	10	9	9	8	7
60–35	384	295	47	27	32	10	10	9	9	8

lack of many *H. convergens* larvae in sorghum was striking. A similar finding was reported by Kieckhefer and Miller (*8*) in a study of aphid predators in cereal crops.

Native beetles were active in sorghum fields through September. They may have had an important role in reducing heavy greenbug infestations during June and July, but parasites of greenbugs may have been more important. By September, many of the adult beetles had moved from sorghum leaves to the sorghum heads, where they apparently were feeding on pollen. A single head often contained 10 to 20 beetles, and there were few insects for food. However, there was no reason to conclude that food was so scarce that beetles had been forced into estivohibernation, as suggested by Stewart et al. (*10*).

Even so, beetles had started to congregate at estivohibernation locations at least by late August. On Mount Scott, the highest elevation in the Wichita Mountains of southwest Oklahoma, there were groups of beetles on weeds, in crevices, and even under beer cans near a blacktopped parking lot at the summit. The beetles did not seem to be bothered by the visits of people to the area or by the temperature, often in the 90's during this time of year. Mount Quartz is the highest point near Altus, Okla. At the time of our visit, the vegetation had recently been burned off. At the highest elevation there were over 100 roasted beetles per square foot and a few live ones. The live beetles apparently had come to the area after the fire. Turning over rocks revealed well-decomposed beetles, thus indicating that the area had been a congregating place for lady beetles in prior years. Mount Quartz has two peaks, one of which is a few feet higher than the other. Beetles were found only on the higher one. In late July beetles were observed in large numbers on Mount Capulin near Clayton, N. Mex., in crevices and on limbs of trees. Again, beetles were grouped only near the top and not at the lower elevations. By October 1, only a few beetles remained on the summit of Mount Capulin. Estivohibernating beetles contained no eggs, whereas beetles collected in the Oklahoma Panhan-

dle showed good formation of eggs upon dissection.

The congregating of beetles in the Sierra Nevada is well known, especially since Hagen's article appeared in the April 1970 National Geographic Magazine (*5*). Less known are reports from New Mexico (Douglas, *2*), Michigan, and several Southeastern States (Sherman, *9*). These observations indicate that lady beetles overwinter at the highest elevation in a region, although the beetle may leave before winter, as indicated on Mount Capulin. Perhaps means could be devised for increasing the numbers and survival of beetles in these locations; and in the spring the congregated beetles could either be collected and released in sorghum fields or allowed to filter down to lower elevations on their own.

CONCLUSION

Hatch and Tanasse (*6*) relate that the release of overwintering *H. convergens* started in California about 1910. The practice was intensified during World War II in southern California, Arizona, Georgia, Florida, and New Mexico. Procedures for storage, shipping, and releasing were strikingly similar to those used today—the main change has been the cost of the beetles. The last sentence of the article states that there is the ". . . persistence of a scientifically unjustified attempt at biological control 20 years after its disqualification." Presumably, "disqualification" was based on reports by Davidson (*1*) that the beetles did not remain in the release area, and this conclusion is supported by our own studies. Wadley (*11*) states (p. 368) that coccinellids "rank high as efficient aphid enemies not only because of the high destructive and reproductive powers shown, but because of hardiness and other characteristics." Thus, if the migratory urge of lady beetles can be controlled, the effective suppression of greenbugs may be possible. Unfortunately, we found no solutions for curbing beetle migration.

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